A SELECTIVE MULTICOMMODITY NETWORK FLOW ALGORITHM FOR AIR TRAFFIC CONTROL

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1 INTRODUCTION

The United States Federal Aviation Administration (FAA) continually seeks and develops ways to improve air traffic management. Current practices include ground delays, miles in trail restrictions, and rerouting. Some traffic control procedures initiate at a central flow control facility, and some are generated at regional or local facilities. In each case, traffic flow management (TFM) staff ensure that the flow of traffic does not exceed a limited, safe capacity at an airport or in the en route airspace.

Because several types of TFM practices occur simultaneously at any time throughout the day, field personnel perceive the need for a more integrated system.

Until 1991 modelers had been unable to develop an optimization model that integrated the multiple TFM practices. What limited the pre-1991 models was an inability to represent ground delay and air delay simultaneously at multiple locations, headed for multiple destinations. Since 1991, several optimization models have broken this barrier, although still in the research and development stages.

The Space-Time Network (STN) model, developed as part of that research effort, had two major thrusts: one in model formulation and one in its solution methods. The model formulation represents the NAS as a multicommodity network. All traffic headed for the same destination constitute one commodity. The solution method differs from traditional single and multiple commodity minimum cost flow algorithms. In the STN solution method, the initial ba-
sic feasible solution derives from the straightforward ground delay program. Subsequent improvements are found by a method of partial search.

Section 1 describes the nation-wide operational air traffic management problem. This section also summarizes models that attempt to solve it. Section 2 formulates the basic STN model. Section 3 describes the network solution method of partial search and some computational experience. Section 4 summarizes the STN formulation and its solution method.

2 PROBLEM DESCRIPTION

Most commercial airlines generate daily flight schedules one to six months in advance. These advance schedules are planned to accommodate the flying public and to take advantage of good weather and normal equipment maintenance. When severe weather or extreme equipment failure occurs, these advance schedules do not apply. Strong winds can change flight times. Snowstorms, sleet and fog can decrease airport capacities. Thunderstorms can temporarily reduce some airspace capacities to zero.

The FAA engages in airspace design in cooperation with other aviation communities – commercial airlines, general aviation, and the military. Airspace design includes partitioning the airspace into administratively manageable areas. The NAS is divided administratively into 20 Air Route Traffic Control Centers (ARTCCs) in the contiguous United States. These are further partitioned into approximately 700 airspace sectors.

A sector is a piece of airspace with well defined, albeit imaginary three-dimensional boundaries. At any time of day or night, any given sector is under the responsibility of one and only one air traffic control team.

We use the term capacity throughout. We define the capacity of a facility (i.e., airport arrival capacity, airport departure capacity, airspace sector capacity) as the number of aircraft that can safely pass through the facility in a time period of given length. The capacity of a sector of airspace, therefore, is a function not just of its volume in cubic miles. A sector's capacity also depends upon the number of aircraft that its air traffic controllers can safely manage.